Predicting activity and workload in general practice from the demographic structure of the practice population

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***Objectives*: The managerial requirements of budget-setting and performance monitoring in general practice (primary care) in the UK require an understanding of the causal relationship between practice activities and the characteristics of both the practice and its patients. This study sought to model the determinants of three major components of general practice activities (consultations, prescribing costs and referrals to secondary care), paying particular attention to the influence of the demographic structure of the patient list.**

***Methods*: Stepwise regression analysis was carried out on data for 98 practices in the county of Lincolnshire using 12 independent variables pertaining to patient and practice characteristics plus 14 statistical measures derived from the demographic structure of the patients registered with the practice.**

***Results*: Robust statistical models were estimated for the three dependent variables, of which list size emerged as the most significant independent variable. In addition, six other independent variables, including the patients' unemployment rate, fundholding status and single-handed status, were statistically significant in one or more of the equations. Variables based on the demographic structure of the practice population also appeared in each model. The Jarman score and degree of urbanization did not achieve statistical significance.**

***Conclusions*: Activity and workload in general practice can be predicted from routine data. Such models are of particular value for planning and financial management when demographic change in practice populations is anticipated.**

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Introduction

The general practitioner (GP) plays a pivotal role in British health care because, in the overwhelming majority of cases, he or she represents the first point of contact between the patient and the health care system. As a defining element of their contracts with the National Health Service (NHS), GPs assume responsibility for the health care needs of a list of patients, and every member of the population is entitled to be placed on such a list. It accordingly follows that the care needs of an individual GP's list of patients, and the methods he or she chooses to employ to meet those needs, are major determinants of the day-to-day activity and workload in general practice. The methods or technologies available to GPs are many and various, and include consultations with patients, either in the surgery or in the patient's home. A consultation may lead to the immediate provision of a remedy (e.g. a prescription for drugs), or a subsequent referral to a specialist treatment unit, such as a hospital.

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In addition, the majority of GPs offer services such as night-visiting, health promotion and immunization, and a number with the appropriate qualifications provide minor surgery.

The 1990 National Health Services Act, and the revised GP contract of the same year, introduced a number of radical changes into the management and finance of British general practice. Traditional activities such as consultations continued to be remunerated from the basic practice allowance and capitation fees related to patients' ages. Activities such as screening, surveillance and health promotion, however, attracted additional payments if target levels of coverage were met, and the allowance for night-visiting was increased.[1] Starting in 1991, large practices were able to apply for fundholding status, which entailed the provision of a budget from which prescribing and a limited range of hospital referral costs had to be met. Meanwhile, in view of a general concern about the escalating cost of prescribed medicine, non-fundholding practices were encouraged to remain within indicative prescribing budgets.[2] Since April 1995, the fundholding scheme has been extended. Small practices may now elect to hold a fund covering only staff, prescribing and community health care costs. Meanwhile the range of secondary care services which

may be purchased by the larger fundholders has increased. In addition, a small number of practices have elected to undertake total purchasing. Under this arrangement, the prespecified budget is intended to cover the purchase of all secondary services and practice operating costs. It is anticipated that more practices will become total purchasers in the future.[3]

As a consequence of this re-organization of the NHS, the importance of information has been raised considerably, particularly information relevant to the setting of realistic prescribing and fundholding budgets. The prescribing budget, for example, has to reflect both the prevailing level of patient need within the practice and the costs of medication. The fundholding budgets have to reflect not only prescribing expenditure but also expected numbers and costs of referrals to secondary care, plus necessary staff costs, themselves a function of practice workload. In both cases an important additional factor is the GP's choice of treatment, a decision based on his or her opinion of how a patient's needs are best met. Information is also required to meet the enhanced requirement of monitoring performance, especially with respect to the quality of services and value for money.[4] The negotiation of budgets and the monitoring of performance on a case-by-case basis is expensive in both time and resources. Accordingly, all agencies are looking at ways of employing data collected on a routine basis, as indicators both of expenditure requirements and of performance. In the case of general practice, this involves examining data relating both to patient and to practice characteristics.

Epidemiologists have long been aware that age is an excellent general predictor of morbidity. Following through the line of argument, it would appear that reasonable statistical models (and thus predictions) of workload amongst, and NHS costs initiated by, GPs ought to be partly obtainable from a knowledge of the demographic structure of practice lists. GPs in practices with different patient demographic structures should record different levels of activity and workload, *ceteris paribus*. Indeed, we find that patient age is explicitly incorporated into two indicators currently employed in the budget-setting process in the UK. First, the Jarman index is a weighted scoring of eight variables, one being defined solely in terms of patient age (proportion of patients under 5 years old). This index was developed from extensive surveys in which GPs were asked to indicate the characteristics of patients which necessitated disproportionate amounts of effort on their part.[5,6] More, rather than fewer, patients of these ages within a practice list thus represent the likelihood of more GP workload being required to service patient needs, *ceteris paribus*. Second, in the light of empirical evidence suggesting a positive association between age and the use of medicines,[7,8] a move has been made towards the use of a weighted capitation formula in determining the prescribing budget. Patient numbers on GPs' lists can be translated into prescribing units (PUs) by the application of an age-related weighting scale. Health authorities have been advised that they might use weightings based on ASTRO-PUs to adjust the prescribing allocations otherwise based on historic costs,[9] the ASTRO-PU being based on a set of arbitrary integer weightings allocated to each of nine age groups for each sex within the practice list.[10] Prescribing costs are currently recognized as key 'profile indicators' of practice activity, while the Jarman score has become a 'secondary indicator', providing supporting information regarding each practice's behaviour.[11]

In spite of their usage, it should be noted that very few validations of either the prescribing unit method or the Jarman index have ever been undertaken, and those that have tended to point to certain weaknesses. The architects of the ASTRO-PU themselves acknowledged that their model accounted for only a small proportion of the variation in prescribing expenditure between practices. Recent research has indicated the importance of practice management, such as generic prescribing and the use of practice formularies, rather than patient characteristics in influencing prescribing costs.[12] There are grounds for believing that the impact on workload of the health care needs of both the very young and the unemployed are underweighted in the Jarman index.[13] Other researchers have argued that single-factor explanations, such as unemployment alone,[14] might prove at least as successful as multifactor explanations in explaining health care needs.

This paper presents the results of statistical modelling of the determinants of the activities and workload of GPs in Lincolnshire, based on routine data for 1993. The independent variables include practice factors, such as whether or not it is fundholding, and patient factors, such as the level of social deprivation. In view of the recognized importance of practice demography, particular attention is devoted to analysing the impact on GP activity of the age structure of practice lists. We have chosen to formulate the problem in a manner which overcomes certain weakness in existing age-related indicators. The dependent variables chosen for the analysis are three measures of GP activity and workload: namely, consultations, prescribing costs and referrals to hospital. Given that our concern is to model the workload accruing to, and NHS costs and activities generated by GPs, each variable is expressed per GP per annum.

Methods

A clear theoretical deficiency exists with respect to the definitions of age variables in existing formulations purporting to assess the impact of age on health service activity. Following the conventions of most national published data, the resource allocation criteria all employ year-banding of ages as independent variables – e.g. 0–4, 5–9 years, and so on. Whilst banding has a certain convenience and economy of information, the choice of ages to be included within the age bands is, of course, essentially arbitrary. Specific information on the importance of any one individual age *within* a band is inevitably downgraded within the average *for* a band. When constructing causal models in which the age variables are

based on age bands, we therefore run the risk of prespecifying the model in an inappropriate manner. There is no reason *ex ante* to expect arbitrary age bands to produce good statistical results within an explanatory model; indeed, the definition of age bands should, more properly, be *derived* from the results of modelling. However, in reality, when more than 100 individual age-years are represented in the population, the permutations of ages into possible age bands of variable length approaches the infinite. This is especially so as there is no intuitive reason why proximate ages should necessarily be grouped into the same band; 6-year-olds, for example, may actually have more in common with 8-year-olds in terms of resource utilization than they do with 7-year-olds. The obvious alternative of using data for each individual age as an independent variable in itself rapidly erodes the degrees of freedom within a statistical model. We have therefore chosen a compromise solution, in which a small number of variables retains or embodies the information of the individual ages in the practice age distribution.

Following from the work of Karl Pearson a century ago, it is now established that:

> A knowledge of the moments, when they all exist, is equivalent to a knowledge of the distribution function: equivalent, that is, in the sense that it should be possible *theoretically* to exhibit all the properties of the distribution in terms of moments [ref. 15, p. 89].

In practice, this result appears to hold for well-behaved distributions up to the fourth moment. It is accordingly possible to employ statistical values based on each of the four moments as elements of a unique description of each patient age distribution. Having obtained the age structure of all Lincolnshire practices (numbers of patients of each year of age in each practice), we therefore calculated the mean (hereafter M1), standard deviation (M2), coefficient of skew (M3) and coefficient of kurtosis (M4) for each distribution.

The dataset from which the models were constructed comprised four components:

1. M1 through M4 for each practice. As it is conceivable that moments are influential in conjunction rather than in isolation, we included all permutations of second-order interaction terms, including squares, giving 14 age variables in total. In that which follows, interactions are denoted by double numbers; thus M24, for example, refers to the product of standard deviation and kurtosis, whilst M33 refers to skew squared.
2. The three activity or workload variables: total GP consultations (surgery and home visits combined), the net ingredient costs of prescribed medicines and referrals to hospital. All are expressed per GP per annum.
3. Nine continuous independent variables, reflecting patient and practice characteristics other than age. Descriptive statistics of these and the three dependent variables are presented in Table 1. The Jarman score and the unemployment rate were included as potential explanatory variables on the basis of the research evidence previously cited. Rural practice payments are calculated essentially on the basis of patient–surgery distances and are thus a measure of urbanization (or lack of it). Census-defined permanent sickness and the proportion of the list resident in care institutions are proxies for morbidity. The gender distribution of the list was also included as a plausible explanatory factor *ex ante*, on the grounds that male and female morbidity patterns are known to differ. The positive impact of average list size on activity and workload has already been demonstrated in other studies.[16,17] The employment of nurses in general practice has increased substantially in recent years,[18] so the practice nurse time employed per GP was included as a variable on the grounds that nursing input might represent a means by which GPs could economize on consultations. The number of branch surgeries operated by the practice may be taken as a measure of the ease of patient access to primary care.
4. Three binary dummy variables related to practice characteristics, namely, whether or not the practice was fundholding, registered as a dispensing practice or single-handed (i.e. run by a single GP). Fundholders in Lincolnshire have already been shown to be low-cost prescribers[19] although the impact of such status

Table 1 Descriptive statistics

Variable	Mean	SD	Minimum	Maximum
Independent variables — patients				
Jarman score	−2.6	10.4	−24.2	23.0
Unemployment (%)	8.1	3.2	4.5	18.2
Rural practice payment per patient (£)	0.3	0.2	0.0	0.7
Proportion of list permanently sick (%)	3.7	1.1	1.9	8.0
Proportion of list in care institution (%)	1.2	1.3	0	5.0
Proportion of list which is male (%)	48.9	1.9	39.8	56.5
Independent variables — practice				
Patients per GP	1904	540	713	3765
Practice nurse hours per GP per week	15.5	9.5	0	60.5
Number of branch surgeries operated	0.8	1.2	0	5.0
Dependent variables				
Prescribing cost per GP per annum (£)	145 780	54 030	38 825	352 856
Consultations per GP per annum	7132	2915	2490	16 868
Referrals per GP per annum	357	193	78	1244

on other activity variables is presently ill understood. Practices permitted to dispense their own prescriptions predominate in rural areas and are believed to be high-cost prescribers, owing, in part, to positive financial incentives.[20] Single-handed practices differ from all others in that they are not based on partnerships, implying that the dynamics of practice management are fundamentally different.

Complete data encompassing all these variables were available for 98 (93%) of the 104 Lincolnshire practices, comprising 307 GPs. The proportion of fundholding, single-handed and dispensing practices in the sample was 19%, 18% and 58%, respectively.

Model-building proceeded by running a backward stepwise ordinary least squares regression for each of the dependent variables, using all the independent variables in the dataset. An absence of simultaneity in the system (by excluding the other two dependent variables) is thereby assumed, and this we justify on theoretical grounds. Whilst it is true that a consultation is likely to prefigure both a referral and prescribing expenditure, it is not clear that any direct causality can be attributed. From Table 1, it is evident that, on average, consultations outnumber referrals in a ratio of around 20:1. Therefore it is reasonable to infer that consultations lead to referrals in only a tiny minority of cases and that most consultations relate to the services offered by the GP specifically. Obviously, in circumstances where consultation does lead to referral, both events should more properly be attributed to the morbidity characteristics of the patient. Consultations frequently prefigure prescribing, although the cost of the items prescribed is, again, more properly described as a function of the patient's condition than of the consultation itself. Moreover, a high proportion of all prescriptions in any one year are repeats, which many practices issue automatically and without requiring consultations. Finally, the possibility of substituting prescribed drugs for hospital referrals certainly exists, although it is confined to a very narrow set of circumstances; prescription of drugs for asthma is one example.[21] Again, such drugs are not necessarily the most costly.

Results

The Figure displays four pairs of examples of the age distributions of practice lists, each pair representing the practices which recorded the extreme values of the range for M1 through M4. These ranges were: mean 33.0–50.8 years, standard deviation 20.9–24.4, coefficient of skew –0.44 to 0.58; coefficient of kurtosis 1.91–2.51. The values of M1 through M4 for Lincolnshire as a whole (based on a summation of the numbers for each age across all practices) were 40.67, 23.46, 0.11 and 2.01, respectively. Inspection of the Figure attests to the high variability of demographic structures, suggesting that practices are likely to be servicing quite disparate types of patient need. The practice with the lowest mean age also recorded the lowest standard deviation.

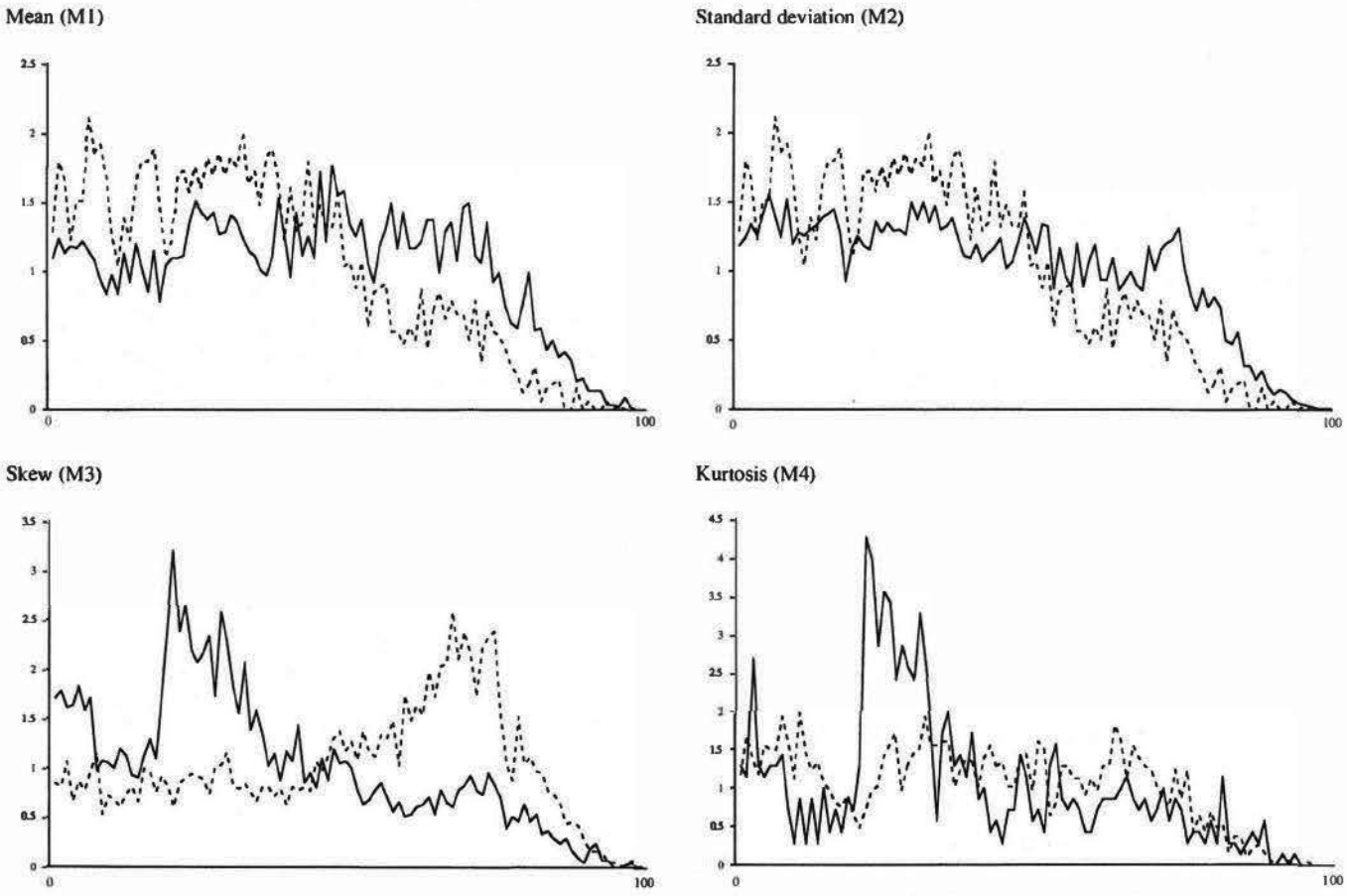

Figure Frequency distributions of patient ages (%), based on extremes of four statistical measures (dotted = lowest; solid = highest).

Table 2 Model estimates

	Prescribing cost		Consultations		Referrals	
	β	t-Ratio	β	t-Ratio	β	t-Ratio
Constant	855 620.0	1.94	−3863.7	−0.83	18 831.0	3.95
Dispensing practice? (1 = Yes, 0 = No)	25 091.0	3.92				
Fundholding practice? (1 = Yes, 0 = No)	−15 537.0	−3.54				
M1					−963.7	−4.03
M12	1083.0	2.30			21.7	4.05
M13			−166.8	−2.29		
M14	−10 786.0	−2.10	−249.8	−2.24	209.8	3.92
M2	−77 077.0	−2.11				
M24	16 106.0	1.84	532.2	2.24	−395.6	−4.02
M33					2291.0	3.33
Practice nurse hours per GP per week			−52.3	−1.83		
List size per GP	83.5	13.83	4.0	9.97	0.2	8.33
Proportion of list which is male (%)					2571.3	2.42
Single-handed? (1 = Yes, 0 = No)			1799.0	2.76	−101.9	−3.23
Unemployment (%)	2106.7	2.09			−15.7	−1.88
R-squared	0.81		0.61		0.47	
Adjusted R-squared	0.80		0.59		0.41	

Table 2 presents the ordinary least squares model results, the *t*-ratios being based on White's procedure for adjusting standard errors in the presence of heteroscedasticity.[22] Five of the 12 independent variables, including the Jarman score, did not achieve statistical significance in any of the three models. This suggests that they are not as efficient as the included variables in explaining the observed variations in activity and workload.

Discussion

It is clear from our results that average list size exerts a major impact on all three activities, although this result is to be anticipated on the grounds of intuition and previous research findings. The statistical significance of the coefficient for this variable, and of the others in the equations, runs counter to the hypothesis that multicollinearity is present, implying that all the variables identified must contribute independently to an explanation of activity. Half of the 14 age variables achieve significance, five of them as interaction terms. This implies that, for example, in the prescribing cost equation, mean patient age is significant only in combination with standard deviation and kurtosis. It is evident that the statistical measures derived from all four moments are relevant in explaining each of the three dependent variables, the exception being skew (M3) in the case of prescribing costs. This finding provides strong support for our implicit hypothesis, namely, that GP activity is, in some degree, a function of the overall shape of the demographic structure of the practice population.

Fundholding and dispensing status are significant influences on prescribing costs, again a result in line with previous findings,[19,20,23] whilst the hypothesis that practice nurses permit economies in GP consultations receives confirmation. Single-handed practices appear, by their very status, to take on above-average consultation workloads. This might be attributable to these particular GPs' attitudes to proper patient management. The relevance of such a factor has already been demonstrated with respect to night-visiting rates.[24] Alternatively, the lower consultation workload of partnerships might be attributable to the existence of more general economies of scale. Of the three equations, referrals to hospital is the least well explained. Similar failings in causal identification have been reported elsewhere in the literature.[25,26] A lack of evidence of association, as provided by the models, is equally informative. Our proxy measures for morbidity and urbanization fail to achieve statistical significance, supporting the findings of others in failing to validate the explanatory power of the widely used Jarman index.

Models of this nature provide precise insights into causal associations between certain patient and practice characteristics and GP activity. For example, differentiation of each of the Table 2 equations provides estimates for the elasticities of the four age variables, M1 through M4. Coupled with the appropriate values of coefficients for other variables, it is possible to predict how practices might be expected to perform, given their demographic structures. Table 3 presents data on the expected consequences of a 1% increase in M1 through M4, using the Lincolnshire average values as the base estimate from which changes are measured. To make the application of the models more concrete, Table 4 presents comparisons of predicted activity and workload for the set of age distributions presented in the Figure. In each case, Lincolnshire average values are assumed for all other variables, with the equations being re-estimated for the differing values of M1 through M4. The lowest value of each moment forms the base estimate in each case.

Table 3 Elasticity estimates (%), for a 1% increase in the age variables

	Prescribing cost	Consultations	Referrals
Mean (M1)	1.03	−2.95	−3.69
Standard deviation (M2)	−0.10	3.49	5.79
Skew (M3)	0.00	−0.11	0.17
Kurtosis (M4)	−0.84	0.65	−4.30

Table 4 Differences in activity implied by extreme variations in age distribution parameters (distributions as in the Figure; percentage change, lowest to highest)

	Prescribing cost	Consultations	Referrals
Mean (M1)	17.94	−7.73	−51.60
Standard deviation (M2)	9.65	0.36	−9.96
Skew (M3)	−31.11	8.89	−29.09
Kurtosis (M4)	−17.48	−11.73	15.62

Thus, in the comparison of the extremes of kurtosis for example, the distribution with the highest kurtosis would give rise to less prescribing cost and consultations but more referrals, than the distribution with the lowest kurtosis, *ceteris paribus*. To re-state the point, these are estimates of variations in practice activity and workload which may be ascribed solely to differences in the demographic structure of the patient list.

Such models offer considerable scope for prediction of future activity and workload of relevance to budget-setting. Let us consider an example and, for simplicity, we shall regard Lincolnshire as a single practice and assume that the number of GPs remains constant, as do all the other parameters except for age. Between 1981–1991, the population of the county (currently approaching 600 000) grew by approximately 3000 persons each year. Virtually all of this increase was accounted for by immigration and the most significant class of immigrants was the elderly, seeking to retire in the eastern coastal areas.[27] Adding 3000 persons to our base population, with ages normally distributed around 67 years, leads to the prediction of increases in prescribing costs, consultations and referrals of 1.3% 0.5% and 0.4%, respectively. Were an influx of the very elderly to occur (ages distributed around 85 years), these values would be 1.1%, 0.9% and 3.3%, respectively.

Analysis of demographic impact is clearly of importance to a purchaser in assessing its overall resource requirements. However, because the impact on changing workload and activity initially manifests itself at the practice level, analyses are probably far more important at that level. The expected addition of new patients to a practice, with ages located on the appropriate predicted distribution, would require the adjustment of M1 through M4, plus any other appropriate parameters as specified by the models. For example, practices located in urban centres are likely to experience demographic change centred on the very young. Again using the notion of Lincolnshire as a single practice, the arrival of 3000 individuals with ages normally distributed around 4 years would give rise to increases in prescribing costs, consultations and referrals of 0.3%, 2.6% and 5.9% per GP, respectively.

The models have identified a range of factors determining activity and workload in primary care. More specifically, we have isolated the influence of patient age, which enables us to account for interpractice variations in activity and workload in terms of the age structure of the patients which the practice serves. Such analyses can serve as a basis for decisions such as whether or not a practice needs more resources to cover prescribing costs or hospital referrals as a result of anticipated changes in its patient age distribution or whether its performance could be deemed satisfactory given the constraints imposed by the ages of its patients.

This analysis of practice activity is, of course, specific to a particular dataset for Lincolnshire, an area which can hardly be regarded as typical in health care terms. It is one of the most rural counties in England, with the highest recorded mean prescribing cost per patient.[28] However, as all the data used are routinely collected throughout the country, there is no reason why the analysis could not be replicated elsewhere. This would serve to validate the model and test the robustness of the equations. It would be unwise to employ our results in a policy context without such validation.

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